MONTGOMERY & STIEFEL

Ice and Refrigeration in Connection with the Central Station

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Monastery Hill Bindery

ICE AND REFRIGERATION

IN CONNECTION WITH THE CENTRAL STATION

BY

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AND
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THESIS

FOR THE

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

HARRY EDGAR MONTGOMERY & IRA BROKAW STIEFFEL

ENTITLED ICE AND REFRIGERATION IN CONNECTION WITH THE CENTRAL STATION

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF BACHELOR OF SCIENCE IN ELECTRICAL ENGINEERING

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ICE AND REFRIGERATION IN CONNECTION WITH THE CENTRAL STATION.

I. INTRODUCTION.

It is the purpose of the writers to give a method of determining the approximate cost of operating an ice and refrigeration plant in connection with the central station, and to show that it is a paying proposition for the central station manager. Only the more common refrigeration systems, namely, compression and absorption, with ammonia as a medium, have been discussed in detail. Some data has been gathered from technical articles, some from books of commercial plants, but most of it is purely theoretical. Estimates on the cost of machinery and apparatus have been procured from some of the leading manufacturing firms, namely, The York Manufacturing Company, and the Carbondale Machine Company. Actual data on the cost of operating such plants is very hard to obtain. In most cases where the refrigeration system is operated with the central station, the books of the two departments are not kept separate; and those companies who do keep their books separate are very reluctant about giving out information, except in a general way. Therefore, it has been necessary to make certain assumptions and to compare the results obtained with the actual data at hand.

II. VARIOUS REFRIGERATING SYSTEMS.

The ammonia system, being the most common, will first be discussed. Of this class, the compression system is the more common and consists fundimentally of four parts. First, there is a compressor, which is usually a steam or motor driven unit. Generally this is single acting, the compression taking place in the head end, the pressure being about one hundred and eighty pounds per square inch. The compressor discharges the ammonia into the cooling coils, which are generally surface cooled by running water, and in these coils the gas becomes a liquid. The liquid passes thru an expansion valve, which is the third step of the cycle. This is a wire-drawing process in which the pressure is reduced to about ten or fifteen pounds per square inch. In passing the valve the liquid ammonia becomes a gas, due to expansion, and absorbs heat during its passage thru the expansion or freezing coils, thereby completing the cycle.

There are two compression systems in general use, the dry and the flooded. The main difference between the two is the condition of the ammonia in the expansion or freezing coils. In the dry system ammonia gas alone is present, while in the flooded liquid ammonia is mixed with the gas. The dry system was originally employed, but the advantages claimed for the flooded system are bringing the latter into more general use.

In the flooded system the freezing coils contain liquid ammonia and gas at all times, but not in any definite proportion. An accumulator, which separates the liquid ammonia from the gas,

is placed between the coils and the intake for the compressor. Some of the liquid ammonia is often allowed to enter the compressor, thus keeping down the heat, and dispensing with the water jacket around the compressor cylinder. The advocates of the flooded system claim that the heat absorbing surface of the coils will transmit about seventy-five percent more heat per square foot of surface per degree difference in temperature of the mediums when there is liquid on both sides of the coils than when operated with gas on the inside and liquid on the outside.

The absorption system is similar to the compression system in that there are four distinct steps. The generator takes the place of the compressor, and the ammonia gas, instead of being compressed mechanically, is compressed by heating. The gas, after leaving the freezing coils, enters the absorber, where it is taken up by the water. The aqua ammonia solution is then pumped into the generator, where it is boiled by means of steam; usually the exhaust from engines or auxiliaries being used. The ammonia gas is driven off and lead into the cooling coils, the remainder of the cycle being completed in the same manner as in the compression system.

The Sulphur Dioxide system has the same cycle as the compression system described, the difference being that sulphur dioxide is used instead of ammonia as a medium. The machine is very compact, the entire cycle of the medium being enclosed in a hermetically sealed case from which the air has been exhausted. Valves are eliminated in this machine by the use of annular openings in the shaft and trunnions which support the compressor.

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A good idea of the system can be obtained from the cross section of the machine shown in Figure I. The outside appearance is that of a huge dumb-bell, the two ends being hollow globes, one of which contains the compression cylinder.

This cylinder is hung in a vertical position from a shaft rigidily attached to, and running lengthwise thru the machine. To this shaft is fitted a crank to which the piston is attached. The entire mechanism revolves, except the cylinder which is kept upright by a counter-weight. The globe, which contains the cylinder, takes the place of the cooling coils and is partly immersed in cooling water.

The second globe, which takes the place of the freezing coils, runs partly immersed in the liquid to be cooled. Inside of the shaft is a small tube thru which the liquid refrigerant flows into the second globe. Here it absorbs heat, and returns to a gaseous state and as a gas is lead back thru the hollow shaft to the compression cylinder.

Several mediums, which may be used are Ether, Sulphuric Ether, Methylic Ether, Carbonic Acid, and Pictet Fluid. Most of these have been used experimentally only, and, as data is not available, a further description will not be taken up.

Either the plate or the can system of freezing is generally used. By the plate system the ice is frozen in huge flat plates, which are afterwards sawed into commercial sized cakes. In the second system the ice is frozen in upright cans placed in parallel rows in the brine tank. The inside dimensions of these cans are those of an ordinary commercial cake.

Sketch of
Sulphur Dioxide
Machine.

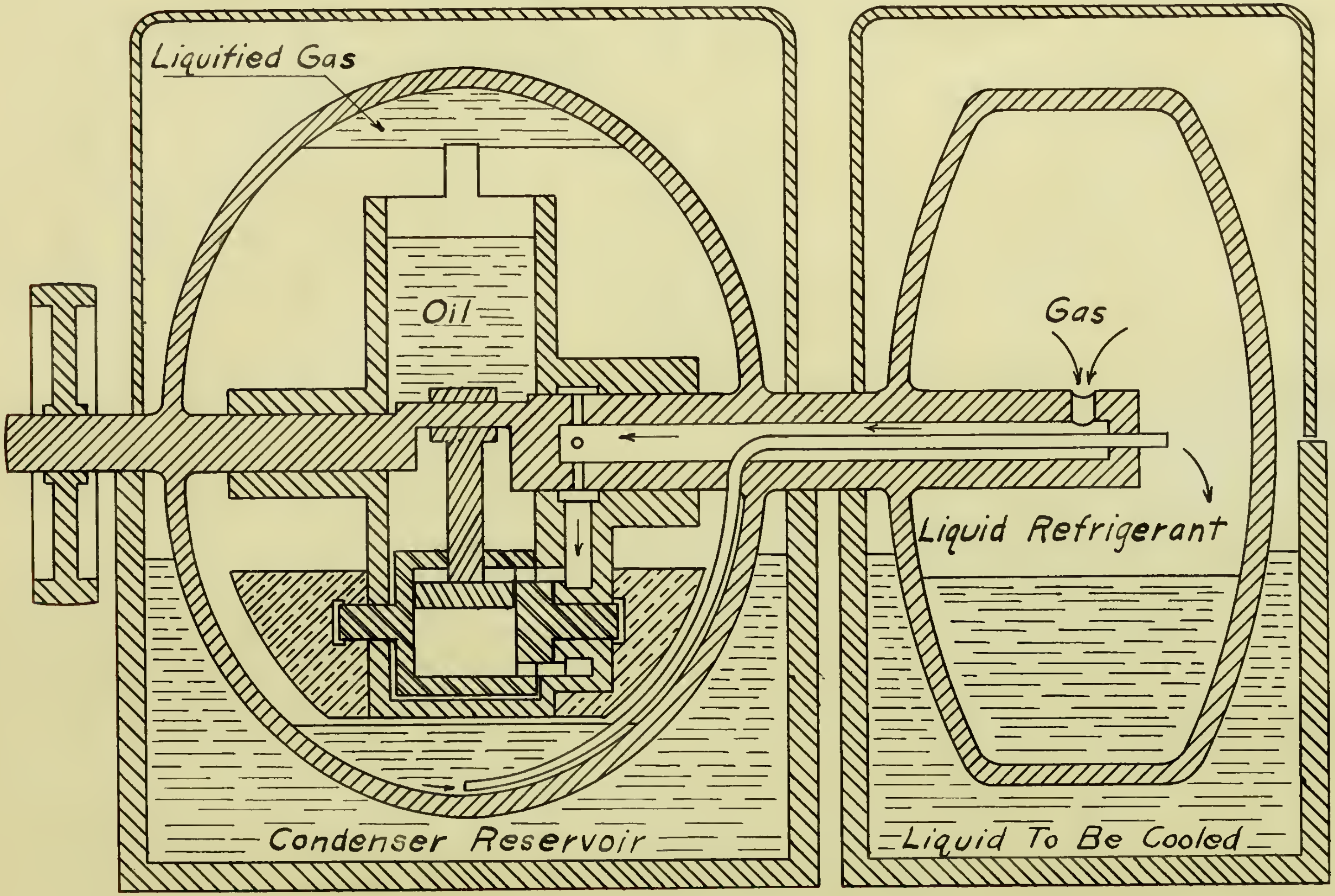


Figure I.

III. CALCULATIONS FOR PROPOSED PLANTS.

In these calculations entirely theoretical plants have been assumed. In the operating expenses of the ice plants, the increase in fuel consumption has been the only charge for power. The cost of labor, interest, insurance, and depreciation on the machinery and buildings has been considered in the final cost per ton of product.

In the different cases, the year has been divided into seasons and a theoretical load curve drawn for each. The same efficiency curve was taken for the different units. Steam consumption curves were assumed for the various systems of operating; the steam engines being taken as ninety-two percent efficient at all loads. From this assumed data the steam consumption for the different seasons has been found as shown in these sample calculations:-

Example:- - Case I. Table I. Line 4.

K.W. and Hours from load curve.

Percent load on Generator. $\frac{260}{300} = 86.6\%$

Efficiency from efficiency curve. $= 94.5\%$

$\text{Input} = \frac{\text{K.W.}}{\text{Eff.}} = \frac{260}{.945} = 275 \text{ K.W.}$

$\text{B.H.P.} = \frac{\text{Input}}{.746} = \frac{275}{.746} = 369 \text{ H.P.}$

Efficiency of Engine = 92%

$\text{I.H.P.} = \frac{\text{B.H.P.}}{\text{Eff.}} = \frac{369}{.92} = 401 \text{ H.P.}$

Percent of total load $= \frac{\text{I.H.P. load}}{\text{I.H.P. Engine.}} = \frac{401}{460} = 87.2\%$

Steam Consumption per I.H.P. Hr. from curve = 14.5#.

Total Steam Consumption = I.H.P. x steam consumption per I.H.P. Hr. x No. Hours. = 401 x 14.5 x 1 = 5830# per Hr.

CASE I.

A Twenty ton compression system ice plant, motor driven, is operated in connection with a Five hundred kilo-watt plant. Two units are employed, a Three hundred kilo-watt generator, driven by a Four hundred and sixty I.H.P. compound condensing Corliss engine, and a Two hundred kilo-watt generator, driven by a similar engine of Three hundred I.H.P. The engines operate under steam pressure of one hundred pounds gage on the high side and four and three fourths pounds absolute back pressure, with twenty percent cut-off.

Data taken from Tables I-VIII of Appendix:-

	1st season.	2nd season.	3rd season.	4th season.
Steam consumption with ice plant.	168320	185940	166776	153140
Steam consumption without ice plant.	150730	142065	119890	136210
Increased steam consumption.	17590#	43875#	46886#	16930#

Total steam consumption per quarter equals steam consumption per day times days per quarter.

1st season.	17590 x 89 =	1565510#
2nd season.	43875 x 92 =	4036500#
3rd season.	46886 x 92 =	4313512#

4th season. $16930 \times 91 = \underline{1540630\#}$
$11456152\#$

Assume quality of steam as 98%

Coal = 11000 B.t.u. per lb.

Feed water temperature = 200°.

Factor of evaporation = $\frac{q + xr - qf}{966.3}$ =

$$\frac{308.5 + .98(880.75) - 168}{966.3} = \frac{1004.5}{966.3} = 1.04$$

Boiler efficiency = 60%.

$\frac{1100 \times .6}{1004.5}$ = 6.57# water evaporated per pound coal consumed.

$\frac{11456152}{6.57}$ = 1743710# coal per year = 871.85 Tons.

Cost of coal = $2.00 per ton.

871.85 x $2.00 = $1743.70 per year.

Investment:-

Cost of buildings, estimated.	$10000.00
Cost of machines, including motors.	12125.00
	$22125.00

Interest, depreciation, and insurance = 15%.

$22125 x .15 = $3318.75

Operating expenses:-

Interest and depreciation.	$3318.75
Coal	1743.70
Labor, Two men for one year @ $2.00 per day.	1500.00
General Expenses.	300.00
Total operating costs.	$6862.45

Ice made, calculated on percent load at which ice machines were operated.

First season.	Half load.	890 Tons.
Second season.	Full load.	1840 Tons.

Third season.	One fourth over load.	2300 Tons.
Fourth season.	Half load.	910 Tons.
Total Ice made during year.		5940 Tons.

$\frac{6862.45}{5940}$ = \$1.156 = cost per ton of ice at platform.

CASE II.

For the second case, a compression system, motor driven, ice plant of Forty ton capacity is operated with a One thousand kilo-watt plant. In the power plant two units are used, namely, one Three hundred kilo-watt generator, driven by a Four hundred I.H.P. compound condensing Corliss engine, and one Seven hundred kilo-watt generator, driven by a similar engine of one Thousand I.H.P. Other conditions are the same as in Case I, except that the ice plant is shut down during the winter months.

Data taken from Tables I-VI of Appendix:-

	2nd season.	3rd season.	4th season.
Steam consumption with ice plant.	363690	366150	379430
Steam consumption without ice plant.	316030	270010	330860
Increased steam consumption.	47660#	96140#	48570#

Total steam consumption per quarter equals steam consumption per day times days per quarter.

2nd season.	47660 x 92 =	4384720#
3rd season.	96140 x 92 =	8844880#
4th season.	48570 x 91 =	4419870#
		17649470#.

Taking, as in Case I, 6.57 pounds water evaporated per

pound of coal consumed.

$\frac{17649470}{6.57}$ = 2686373# coal per year = 1343.2 Tons.

Cost of coal = $2.00 per ton.

1343.2 x $2.00 = $2686.40 per year.

Investment:-

Cost of buildings, estimated.	$15000.00
Cost of machines, including motors.	20100.00
	$35100.00

Interest, depreciation, and insurance = 15%.

$35100.00 x .15 = $5265.00

Operating expenses:-

Interest and depreciation.	$ 5265.00
Coal.	2686.40
Labor, Three men for one year @ $2.00 per day.	2200.00
General Expenses.	600.00
Total operating costs.	$10751.40

Ice made, calculated on percent load at which ice machines were operated.

Second season.	Half load.	1840 Tons.
Third season.	Full load.	3680 Tons.
Fourth season.	Half load.	1820 Tons.
Total ice made during year.		7340 Tons.

$\frac{10751.40}{7340}$ = $1.465 = cost per ton of ice at platform.

CASE III.

The plant of Case I, with the same load curves was assumed, changing the engines from compound condensing Corliss to comp-

ound non-condensing Corliss. A motor driven, compression system, ice plant of the same capacity was operated, and the cost per ton calculated in the same manner as before.

Data taken from Tables I-VIII of Appendix:-

	1st season.	2nd season.	3rd season.	4th season.
Steam consumption with ice plant.	271320	297900	269230	247290
Steam consumption without ice plant.	243080	228880	193670	219720
Increased steam consumption.	28240#	69020#	75560#	27570#

Total steam consumption per season equals total steam consumption per day times days per season.

1st season.	28240 x 89 = 2513360#
2nd season.	69020 x 92 = 6349840#
3rd season.	75560 x 92 = 6951520#
4th season.	27570 x 91 = 2508870#
	18323590#

Taking, as in Case I, 6.57 pounds water evaporated per pound coal consumed.

$\frac{18323590}{6.57}$ = 2790000# coal per year = 1395 Tons.

Cost of coal = \$2.00 per ton.

1395 x \$2.00 = \$2790.00 per year.

Investment:-

Cost of buildings, estimated.	\$10000.00
Cost of machines, including motors.	12125.00
	\$22125.00

Interest, depreciation, and insurance = 15%.

\$22125.00 x .15 = \$3318.75

Operating expenses:-

Interest and depreciation.	$3318.75
Coal.	2790.00
Labor, Two men for one year @ $2.00 per day.	1500.00
General expenses.	300.00
Total operating expenses.	$7910.75

Ice made, calculated on percent load at which ice machines were operated.

First season.	Half load.	890 Tons.
Second season.	Full load.	1840 Tons.
Third season.	One quarter over load.	2300 Tons.
Fourth season.	Half load.	910 Tons.
		5940 Tons.

$\frac{7910.75}{5940}$ = $1.33 = cost per ton of ice at platform.

CASE IV.

An absorption system ice plant of Twenty tons capacity working under Two pounds gage pressure, is operated with the power plant of Case III, instead of the compression plant. The cost per ton is calculated in the same manner as before, the ice plant being charged with the increased coal consumption due to back pressure.

Data taken from Tables I-IV of Appendix.

	1st season.	2nd season.	3rd season.	4th season.
Steam consumption with ice plant.	257660	242480	205375	233040
Steam consumption without ice plant.	243080	228880	193670	219720
Increased steam consumption.	14580#	13600#	11705#	13320#

Total steam consumption per season equals steam consumption per day times number of days per season.

1st season.	14580 x 89 =	1297620#
2nd season.	13600 x 92 =	1251200#
3rd season.	11705 x 92 =	1076860#
4th season.	13320 x 91 =	1212120#
		4837800#

Taking, as in Case I, 6.57 pounds water evaporated per pound of coal consumed.

$\frac{4837800}{6.57}$ = 736350# coal per year = 368.18 Tons.

Cost of coal = $2.00 per ton.

368.18 x $2.00 = $736.36 per year.

Investment:-

Cost of buildings, estimated.	$10000.00
Cost of machines, including motors.	12125.00
Additional cost of erection over compression.	2500.00
	$24625.00

Interest, depreciation, and insurance = 15%.

$24625.00 x.15 = $3700.00

Operating expenses:-

Interest and depreciation.	$3700.00
Coal.	736.36
Labor, Two men for one year @ $2.00 per day.	1500.00
General expenses.	300.00
Assume 10 K.W. per hr. @ 2¢ per K.W.	1752.00
Total operating costs.	$7988.36

Ice made, calculated on percent load at which machines were operated.

First season.	Half load.	890 Tons.
Second season.	Full load.	1840 Tons.
Third season.	One fourth over load.	2300 Tons.
Fourth season.	Half load.	910 Tons.
Total ice made during year.		5940 Tons.

$\frac{7988.36}{5940}$ = \$1.345 = cost per ton of ice at platform.

IV. ACTUAL DATA.

ABSORPTION SYSTEM.

The data of this plant was obtained directly from the books of the company, whose name, by their request, is with-held. This data covers a period of one year, Oct. 31, 1910 to Oct. 31, 1911. The plant under discussion is a Voigt absorption system of Twenty tons capacity, and is operated in connection with a Three hundred kilo-volt-ampere plant. Ice was made during the winter as sold, very little being stored. A refrigerating room, having a capacity of four hundred barrels is part of the building.

The ammonia and brine pumps are steam driven, the rest of the auxiliaries being driven by induction motors.

The cost per ton at platform in this plant has been determined from the operating expenses, which include coal, water, power, labor, repairs, and miscellaneous expenses. In calculating the net earnings interest, insurance, and taxes have been included with the operating expenses to make up the total cost, no accumulating depreciation charges being made.

The following tables show the data as taken from the books:-

Operating costs.

Month.	Wages.	Coal.	Water.	Power.	Supplies.	Repairs.	Misc. Exp.
Nov.	$ 20.00	$ 20.78	$30.35	$	$	$ 5.28	$ 5.51
Dec.	20.00	8.95	28.06				
Jan.	20.00	7.52	32.90				4.23
Feb.	64.50	19.60	31.00	1.80			
Mar.	49.13	31.98	31.00	6.40		14.00	17.10
Apr.	65.00	60.00	31.50	30.00			
May.	90.00	96.60	34.00	56.00		21.46	
June.	197.41	149.45	30.00	133.20	30.00		23.27
July.	228.04	144.50	31.00	130.80	35.00		24.60
Aug.	189.90	144.19	31.00	130.80	35.00		65.31
Sept.	176.90	116.25	30.00	115.20	30.00		
Oct.	114.85	61.60	25.00	96.06	30.00		

General Data.

Month	Ice Pulled	Shrinkage	Oper. cost per ton ice.	Gross Price received.
Nov.	190500#	1850#	$ .724	$6.33
Dec.	84900	0	.598	5.60
Jan.	63700	0	1.890	6.00
Feb.	168300	0	1.440	6.00
Mar.	256380	280	1.568	6.00
Apr.	500000	305	1.000	7.00
May.	839540	2360	.952	6.20
June.	1243320	3840	1.016	6.20
July.	1222700	3110	.950	6.00
Aug.	1227860	2680	.895	6.40
Sept.	975430	3000	.880	6.00
Oct.	559978	6290	1.960	6.40
	7332608#		Av. =$1.156	

Average price per ton at platform.	$6.00
Delivery cost per ton.	$1.50
Cost per ton to load on cars.	$ .24
Amount of ice loaded in car load lots, in pounds	78300.

Earnings.

Capital invested.	$19675.02
Gross income.	15238.95
Total cost, not including delivery.	5113.50
Net Income at platform	$10125.45

The average cost per ton, calculated from operating expenses alone, as taken from the table is $1.156. The cost per ton is considerable higher when the total cost is used, the figure being $1.40.

COMPRESSION PLANTS.

To have a basis of comparison, actual data on two motor driven ice plants, not operated in connection with the central station, but buying their power, has been selected. The tables given were taken from the Electrical World of May 4, 1911. They were originally a part of a paper presented before the Chicago section of the American Institute of Electrical Engineers by Augustus C. Smith, sales engineer of the Cataract Power and Conduit Company of Buffalo, New York.

The first plant, which is located in Buffalo, is a plate system of One hundred tons capacity, using pure spring water. A One hundred ton compressor is driven by a Two hundred horse power, three phase, twenty-five cycle, twenty-two hundred volt, induction motor; the auxiliaries being driven by small motors, ranging from two to seven and a half horse power. The power consumption per ton of ice is shown in the following table:-

Energy Consumption.

1910	Tons of Ice Monthly	Tons of Ice Daily	Max. H.P.	H.P. Hours.	Max. H.P. per Ton	H.P. Hrs. per Ton.
Jan.				10314		
Feb.	1420	50.7	145	98214	2.86	69.2

Mar.	1400	45.2	153	105845	3.38	75.6
Apr.	1168	38.9	139	78933	3.58	67.6
May.	1786	57.6	138	101798	2.40	57.0
June.	1037	34.6	278	120720	8.00	116.4
July.	2294	74.0	280	201791	3.78	88.0
Aug.	1800	58.1	290	209200	4.98	116.2
Sept.	2244	74.8	283	198157	3.78	88.3
Oct.	1115	36.0	149	117363	4.13	105.3
Nov.	1019	34.0	141	98320	4.14	96.5
Dec.	1356	43.7	139	104398	3.19	77.0
	16639			1445053		Av. 86.8

The large values of energy consumption, noted in the table, are, more than likely, due to the compressor and motor being operated at much below their rated load. The assumption has been made that the power cost is two cents per kilo-watt hour, and at this rate the average cost per ton is $1.30.

The second plant is also located in Buffalo, New York, but it is a One hundred ton, can system, using distilled water. Two Eighty-five horse power horizontal tubular boilers are used to furnish steam for part of the auxiliaries, and to supply steam for the distilled water. Two compressors, each driven by a One hundred and seventy-five horse power, three phase, twenty-five cycle, twenty-two hundred volt, induction motor, are used. The energy consumption per ton is given in the following table:-

Energy consumption.

1910	Tons of Ice Monthly	Daily	Max. H.P.	H.P. Hours.	Max. H.P. per Ton	H.P. Hrs. per Ton.
Jan.	1768	57.0	123	87070	2.16	49.24
Feb.	1549	55.3	137	79450	2.48	51.29
Mar.	1903	61.4	221	93760	3.60	49.27
Apr.	2732	91.1	232	164558	2.55	60.23
May.	2651	25.5	257	165488	3.01	62.42
June.	3024	100.8	300	188666	2.98	62.39
July.	3442	111.0	314	219265	2.83	63.70
Aug.	3503	113.0	300	208123	2.65	59.41
Sept.	3514	117.1	291	209027	2.49	59.48
Oct.	3379	109.0	283	185177	2.60	54.80
Nov.	982	32.7	137	88070	4.19	89.68

Dec.	1853	59.8	129	93914	2.16	50.68
	30300			1772568		Av. 58.50

Assuming the cost of power the same as in the first plant, the cost per ton is $ .875.

An average of the cost per ton of the two plants is $1.087. It must, however, be kept in mind that this cost takes nothing into account, except the power consumed. If the cost of labor, interest, insurance, taxes, and depreciation be taken into account the cost per ton will be considerably higher.

NATURAL ICE.

Data on the cost of natural ice is practically impossible to obtain, as the cost, shrinkage, ect., are rarely, if ever, determined. Therefore the cost, in a generally way only, can be found.

It is claimed by those who harvest natural ice that one hundred men at one dollar and a half per day can harvest from six to seven hundred tons per day, depending upon the quality and thickness of the ice. This gives an initial cost of from twenty to twenty-five cents per ton. Seldom is an ice house found at a point suitable for distribution, so hauling is necessary. It costs from fifty to seventy-five cents per ton to haul the ice to a distribution station or platform. Then there is insurance, taxes, and depreciation on buildings, which brings the cost of natural ice to about one dollar per ton.

V. CONCLUSIONS.

Cost of ice per ton at platform.

Theoretical compression system, Twenty ton, with Five hundred kilo-watt plant running compound condensing.	$1.156
Theoretical compression system, Twenty ton, with One thousand kilo-watt plant, running compound condensing.	$1.465
Theoretical compression system, Twenty ton, with Five hundred kilo-watt plant, running compound non-condensing.	$1.330
Theoretical absorption system, Twenty ton, with Five hundred kilo-watt plant, running compound non-condensing.	$1.345
Average.	$1.324
Actual absorption system, Twenty ton, with Three hundred kilo-watt plant, running non-condensing, based on operating costs only.	$1.156
Based on total costs.	$1.400
Actual compression plate system, One hundred ton, power bought from central station.	$1.300
Actual compression can system, One hundred ton, power bought from central station.	$ .875
Average of plants buying power.	$1.087
Natural Ice, approximately.	$1.000

Every year marks an increasing demand for ice. This is largely due to economic causes, one of the main ones being that the standard of living in the United States is advancing every year. At the same time less natural ice is being used, first, because climatic conditions are making it harder to procure in some sections, and second, that, with the agitation for pure food a demand for pure ice is created. Also the winters in the United States are less severe than formerly, and the periods during which natural ice may be harvested are consequently shortened in the middle and southern states. The shortening of the harvesting period calls for more men to work for a shorter time. This presents a difficult problem to the men who harvest natural ice. Then the source of natural ice is rarely near the distribution point, hence it is necessary to transport the ice, usually by wagon. One more obsticle for the natural ice dealer, especially in the middle and southern states, is that some winters may be so mild that no ice can be harvested, therefore it is necessary to ship from a northern source, entailing greater expense.

For these reasons a large field is opened up to the manufacture of artificial ice. It can be made at any time, or continuously, therefore eliminating the necessity of a large number of men for a short period of time. It can be made at the point of distribution as easily, and as cheaply, as at a more remote point. The question of storage may, or may not, enter into the artificial ice proposition, but usually does. The storing of artificial ice eliminates the old method, which entailed much

loss by shrinkage due to saw-dust packing, because, at very little additional expense, the ice can be stored in a clean storage room kept at any temperature necessary by the same brine that freezes the ice.

Then it can be seen why, the field being opened up, there are many artificial ice plants to be found thru out the United States, successfully competing with natural ice.

Now to go one step farther, if the manufacturer of artificial ice can successfully compete with natural ice, as he certainly must do or he would not remain in business, why cannot the central station man compete even better when operating an ice plant directly in connection with his central station? The reply to this question is that he can, for he has a considerable part of his machinery already installed, and his office equipped so that his expenses will be a minimum. This point will now be proven by comparison of the theoretical plants and the actual data given.

A consideration of the results obtained from the calculations on the theoretical plants and from the actual data, show that the ice plant, no matter whether operated compression or absorption in connection with the central station, is a paying proposition. For the four cases calculated the average cost per ton at the platform is $1.324, which compares favorably with the cost of $1.40 as shown by the actual plant operated with the central station. When these figures are compared with the cost per ton of the two motor driven plants, buying power from the central station, it is seen that the central station man still

holds his own. The average cost of ice per ton in the two Buffalo plants, assuming two cents per kilo-watt hour to be the rate paid for power, is $1.087. It should be remembered that this is based only upon power consumed. Taking into consideration the size of these plants, this compares favorably with the cost of $1.156 per ton in the actual absorption plant when based only upon the operating cost. These figures show conclusively that the central station man can successfully compete with the artificial ice dealer and the natural ice man. If men, generating their own power, or even buying their power, can make a success, it stands to reason that the central station man can make money by installing an ice plant in connection with his central station.

Often the central station operator is desirous of increasing his load factor. This can be done by adding a motor load; why not have this load bring in greater profits by driving an ice plant? The load will be increased, and the efficiency of the power plant raised. The same power plant attendants can look after the ice machinery, and the only additional help necessary would be unskilled labor for handling the ice. Again, if he is operating at nearly rated capacity, he may wish to increase his returns. This may be done by adding an absorption system, that is if he is running his engines non-condensing. In this system his steam consumption will be increased somewhat, due to the back pressure on the engines caused by the generator. He will have a small load added due to motor driven auxiliaries.

In these calculations cases have been taken to show that the ice plant can be added successfully for different methods of

operation. If the plant is being run condensing the absorption system is out of the question, but a motor driven plant may be used to increase the load factor. In the case of a non-condensing plant, if the latter is operating sufficiently under its rated capacity, a motor driven plant may be added, or again, if it is operating near full capacity, an absorption plant may be used which will only increase the steam consumption a comparatively small amount, thus working the boilers somewhat harder. So it is seen that for nearly any condition of operation some solution can be offered which will bring profits to the central station management.

Therefore, the ice plant operated in connection with the central station is a paying proposition; for

There is an increasing demand for pure ice, with a decreasing demand for natural ice; and

The companies operating artificial ice plants, independent of the central station, are making a success; therefore

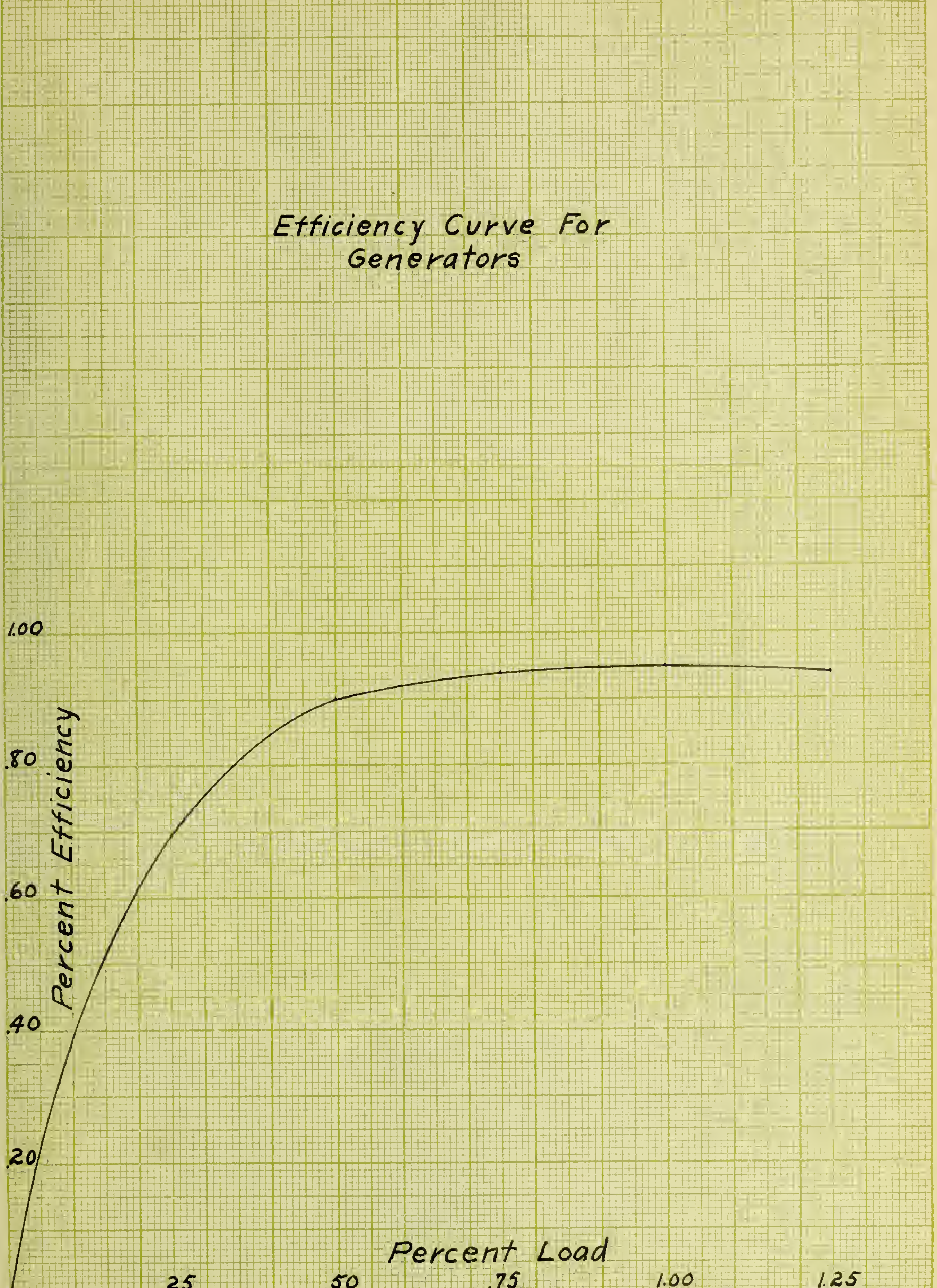
The central station man, operating the ice plant in connection with the central station, can successfully enter the field, as his expenses are a minimum, due to machinery already installed, and a competent operating corps at his command.

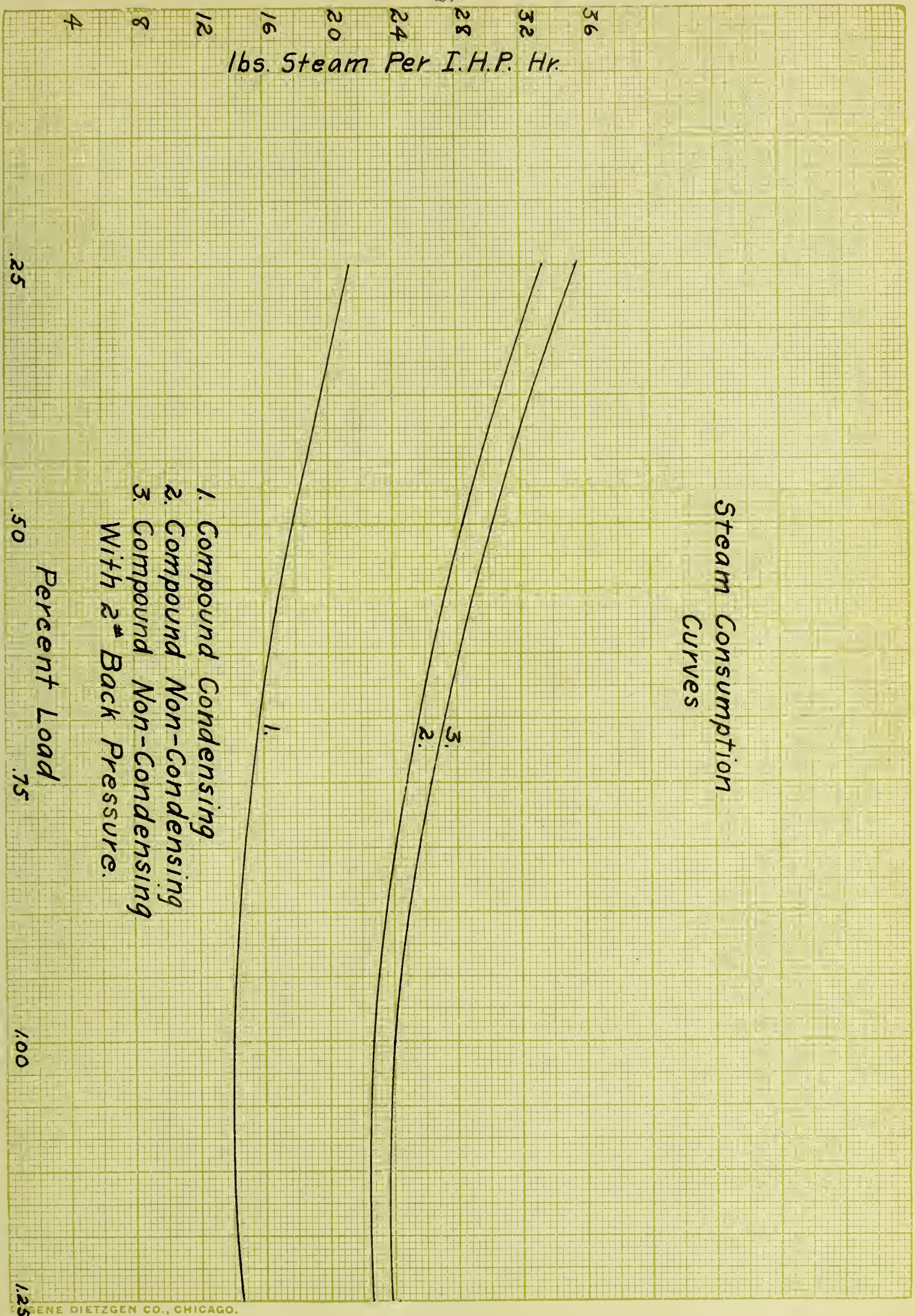
APPENDIX.

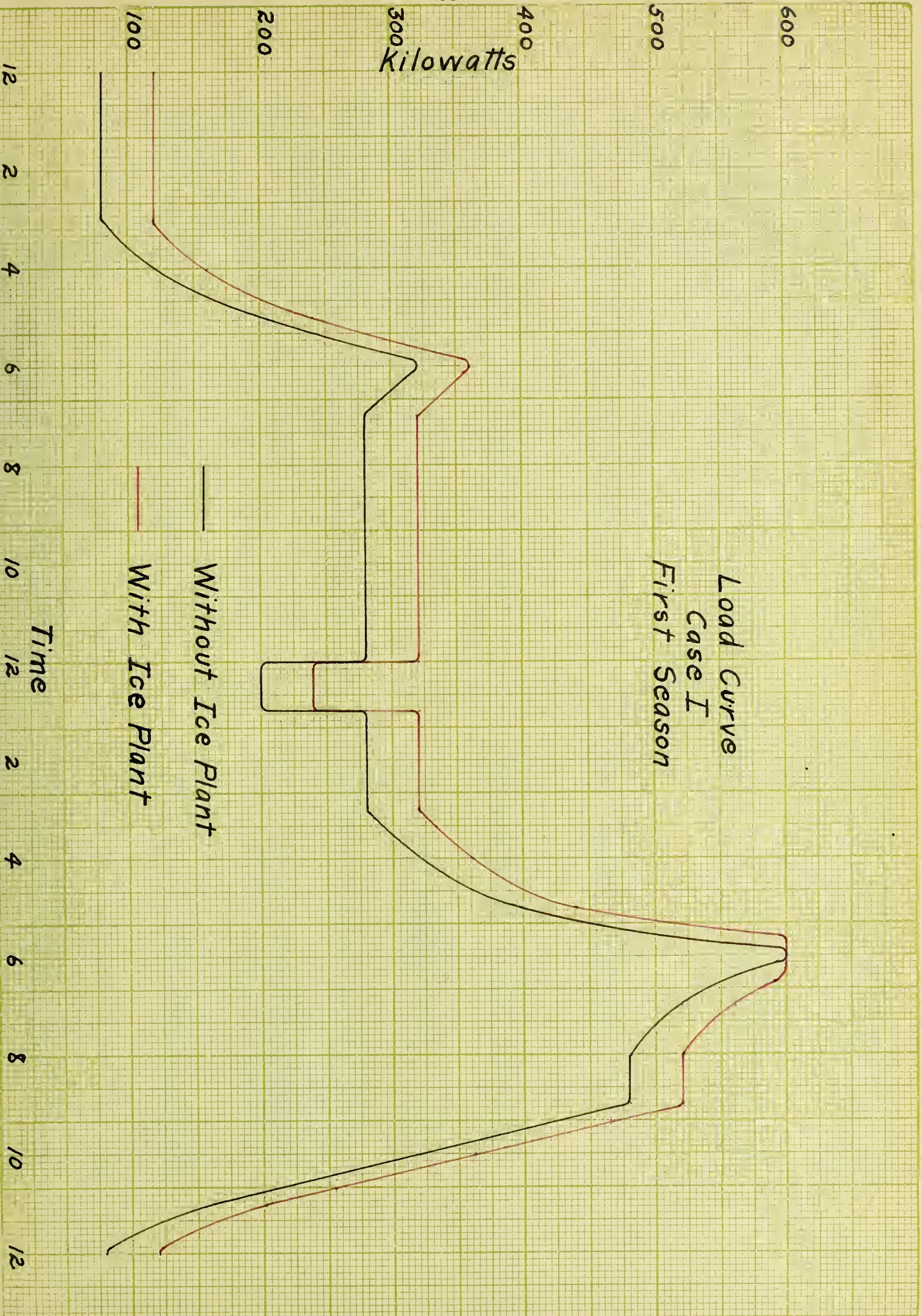
TABLE OF CONTENTS.

INTRODUCTION.

In this appendix will be found the load curves and steam consumption tables for the various cases. For convenience each year has been divided into four divisions, or seasons, which very closely follow the seasons of the year. The same efficiency curve has been chosen for the various generating units, and a steam consumption curve has been taken for each of the different systems of operation. From the load curves assumed for each season the steam consumption has been calculated, and the results tabulated. In each case the engines have been assumed Ninety-two percent efficient, regardless of their load.


Efficiency Curve For Generators
1.00
.80
.60
.40
.20
Percent Efficiency
Percent Load
.25
.50
.75
1.00
1.25


lbs. Steam Per I.H.P. Hr.
4
8
12
16
20
24
28
32
36
Steam Consumption Curves
1. Compound Condensing
2. Compound Non-Condensing
3. Compound Non-Condensing With 2# Back Pressure.
1.
2.
3.
.25
.50
.75
1.00
1.25
Percent Load
ENE DIETZGEN CO., CHICAGO.


Load Curve
Case I
First Season
Kilowatts
100
200
300
400
500
600
Without Ice Plant
With Ice Plant
Time
12
2
4
6
8
10
12
2
4
6
8
10
12

CASE I.

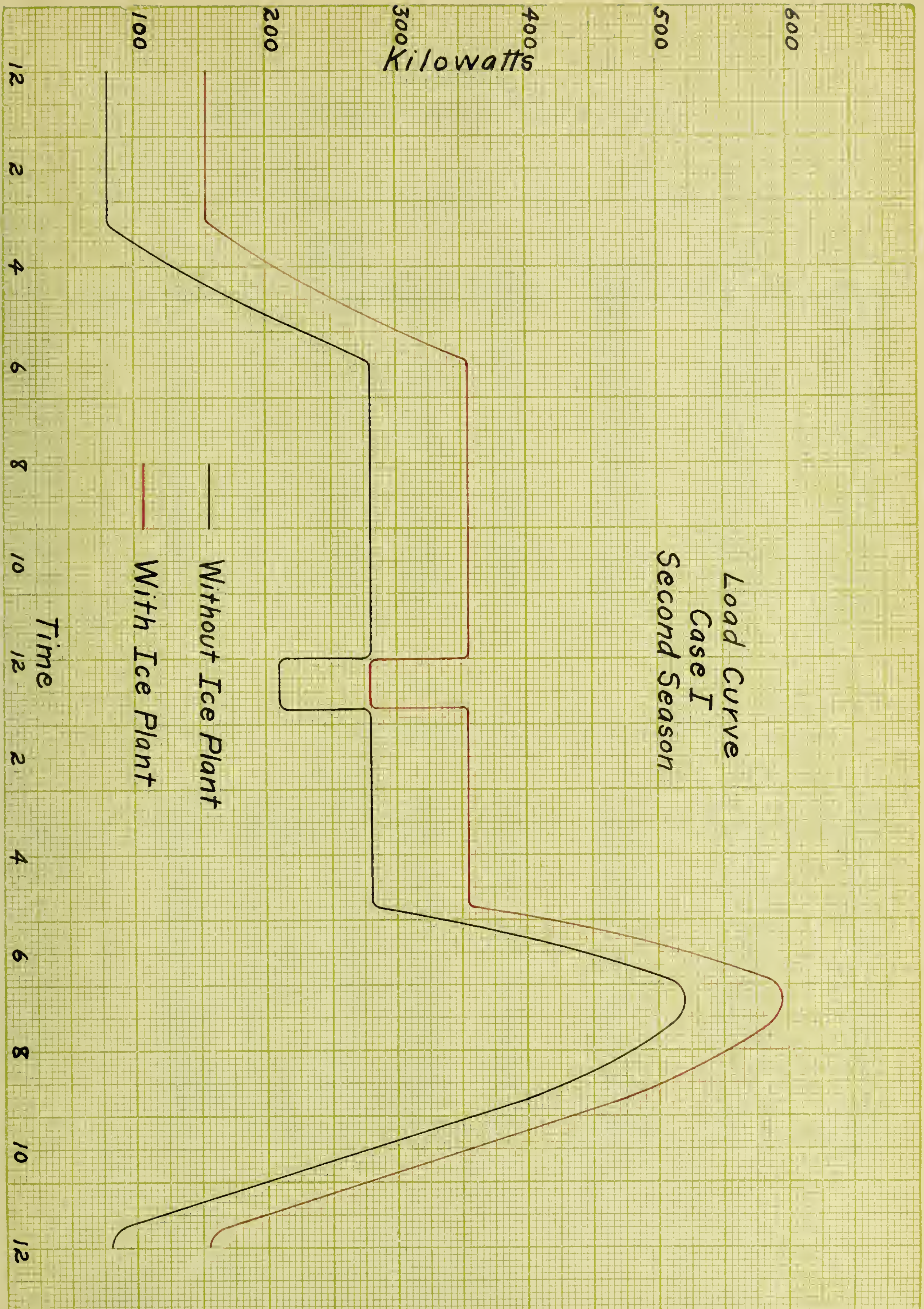
First Season,-- December - January - February.

TABLE I. Steam Consumption without Ice-plant.

K.W.	Hr.	% Load Gen.	Gen. Eff.	Input Gen. K.W.	Eng. B.H.P.	Eng. I.H.P.	% Load Eng.	# Steam per I.H.P. Hr.	# Steam Total
80	3	40.0	84.5	95	127	138	46.0	18.4	7640
95	1	47.5	89.0	106	142	155	51.7	17.6	2730
160	1	80.0	94.0	170	228	247	82.5	15.0	3710
260	1	86.6	94.5	275	369	401	87.2	14.5	5830
300	1	100.0	95.0	316	423	460	100.0	14.0	6440
280	5	93.3	95.0	294	394	429	93.2	14.2	30410
200	1	66.0	93.0	215	288	313	68.1	15.9	4980
280	2	93.3	95.0	294	394	429	93.2	14.2	12180
300	1	100.0	95.5	316	423	460	100.0	14.0	6440
360	1	72.0	93.5	385	515	560	73.6	15.5	8690
500	1	100.0	95.0	526	705	766	100.0	14.0	10720
560	1	112.0	95.0	590	790	860	113.1	14.0	12030
500	1	100.0	95.0	526	705	766	100.0	14.0	10720
480	1	96.1	95.0	505	676	736	96.8	14.0	10300
400	1	80.0	94.0	425	570	620	81.5	15.0	9300
240	1	80.0	94.0	256	343	372	81.1	15.0	5580
120	1	60.0	92.0	130	175	190	63.3	16.1	3030
	24								150730

TABLE II. Steam Consumption with Ice-plant.

K.W.	Hr.	% Load Gen.	Gen. Eff.	Input Gen. K.W.	Eng. B.H.P.	Eng. I.H.P.	% Load Eng.	# Steam per I.H.P. Hr.	# Steam Total
120	3	60.0	92.0	130	175	190	63.3	16.1	9090
135	1	66.6	93.0	145	194	211	70.4	15.8	3340
200	1	100.0	95.0	210	281	306	102.0	14.0	4290
300	1	100.0	95.0	316	423	460	100.0	14.0	6440
340	1	113.0	95.0	358	480	421	113.0	14.0	7300
320	5	107.0	95.0	336	450	489	106.2	14.0	34200
240	1	80.0	94.0	256	343	372	81.1	15.0	5580
320	2	107.0	95.0	336	450	489	106.2	14.0	13700
340	1	68.0	93.0	366	488	530	69.6	15.8	8380
400	1	80.0	94.0	425	570	620	81.5	15.0	9300
540	1	108.0	95.0	570	765	830	109.0	14.0	11600
560	1	112.0	95.0	590	790	860	113.1	14.0	12030
540	1	108.0	95.0	570	765	830	109.0	14.0	11600
520	1	104.0	95.0	548	735	798	105.0	14.0	11170
490	1	98.0	95.0	516	692	752	99.0	14.0	10500
280	1	93.3	95.0	294	394	429	93.2	14.2	6090
160	1	80.0	94.0	170	228	247	82.5	15.0	3710
	24								168320


Kilowatts
100
200
300
400
500
600
Load Curve
Case I
Second Season
Without Ice Plant
With Ice Plant
Time
12
2
4
6
8
10
12
2
4
6
8
10
12

CASE I.

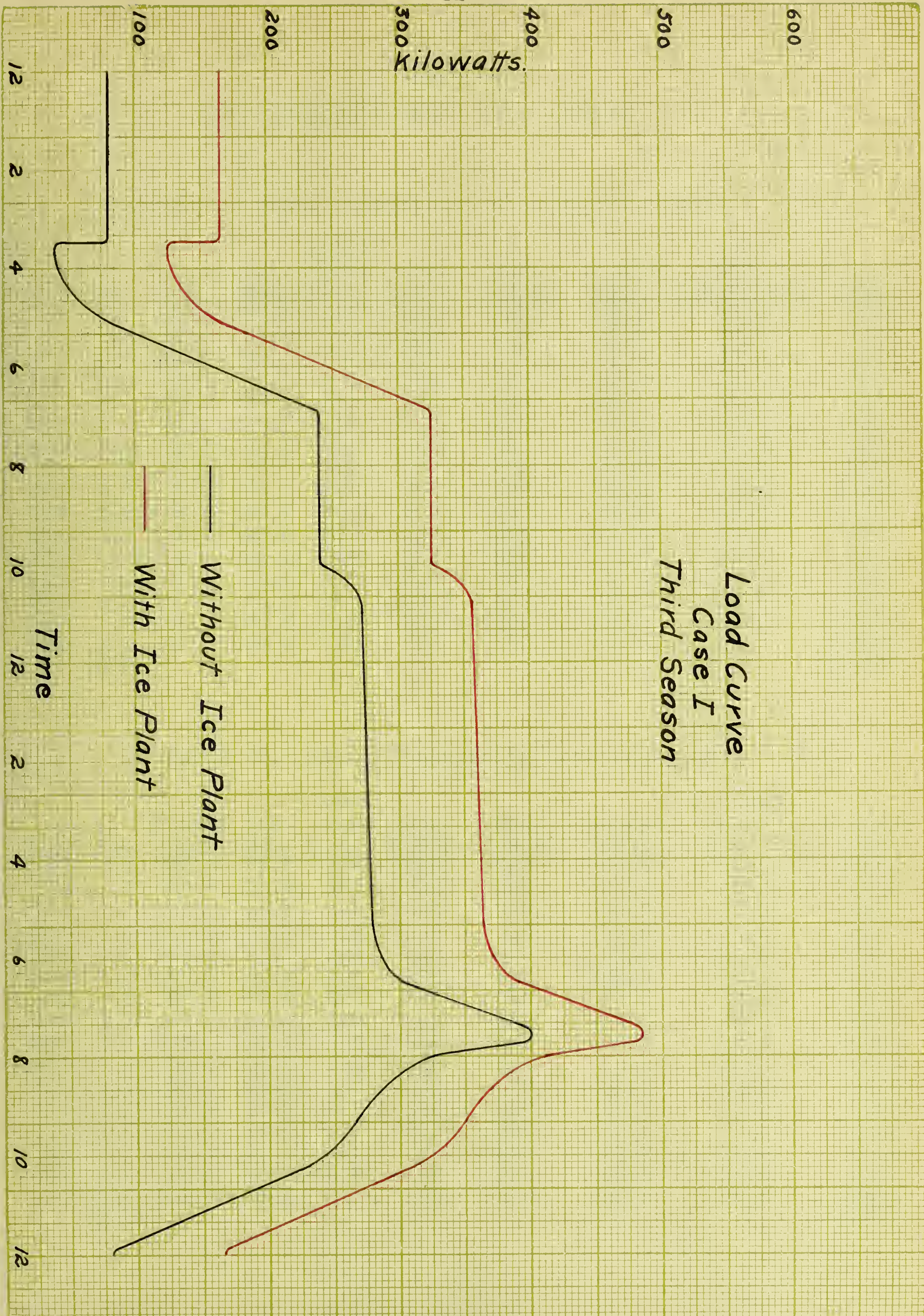
Second Season,-- March - April - May.

TABLE III. Steam Consumption without Ice-plant.

K.W.	Hr.	% Load Gen.	Gen. Eff.	Input Gen. K.W.	Eng. B.H.P.	Eng. I.H.P.	% Load Eng.	# Steam per I.H.P. Hr.	# Steam Total
80	3	40.0	84.5	95	127	138	46.0	18.4	7640
100	1	50.0	90.0	111	149	162	53.8	17.4	2820
170	1	85.0	94.5	180	241	262	87.3	14.4	3775
240	1	80.0	94.0	256	343	372	81.1	15.0	5580
280	6	93.3	95.0	294	394	429	93.2	14.2	36600
210	1	70.0	93.0	226	302	328	71.4	15.6	5120
280	4	93.3	95.0	294	394	429	93.2	14.2	24400
360	1	72.0	93.5	385	515	560	73.6	15.5	8690
480	1	96.1	95.0	505	676	736	96.8	14.0	10300
500	1	100.0	95.0	526	705	766	100.0	14.0	10720
440	1	88.0	95.0	462	620	674	88.6	14.5	9760
340	1	68.0	93.0	366	488	530	69.6	15.8	8380
220	1	110.0	95.0	232	310	337	112.5	14.0	5250
120	1	60.0	92.0	130	175	190	63.3	16.1	3030
	24								142065

TABLE IV. Steam Consumption with Ice-plant.

K.W.	Hr.	% Load Gen.	Gen. Eff.	Input Gen. K.W.	Eng. B.H.P.	Eng. I.H.P.	% Load Eng.	# Steam per I.H.P. Hr.	# Steam Total
155	3	77.5	94.0	165	220	240	80.0	15.0	10800
175	1	87.5	95.0	184	246	268	89.2	14.5	3890
245	1	81.6	94.5	259	347	377	82.0	14.8	5580
315	1	105.0	95.0	332	445	484	105.0	14.0	6780
355	6	71.0	93.5	380	509	554	72.8	15.5	51500
285	1	57.0	91.5	311	419	455	60.0	16.8	7650
355	4	71.0	93.5	380	509	554	72.8	15.5	34400
435	1	87.0	94.5	460	616	670	88.0	14.5	9720
555	1	111.0	95.0	585	784	852	112.0	14.0	11920
575	1	125.0	94.0	612	820	891	117.0	14.1	12600
515	1	103.0	95.0	542	725	788	103.8	14.0	11100
415	1	83.0	94.5	440	590	641	84.4	14.8	9500
295	1	98.3	95.0	310	416	452	100.0	14.0	6330
195	1	97.5	95.0	205	274	298	99.3	14.0	4170
	24								185940


Load Curve
Case I
Third Season
Kilowatts.
100
200
300
400
500
600
Without Ice Plant
With Ice Plant
Time
12
2
4
6
8
10
12
2
4
6
8
10
12

CASE I.

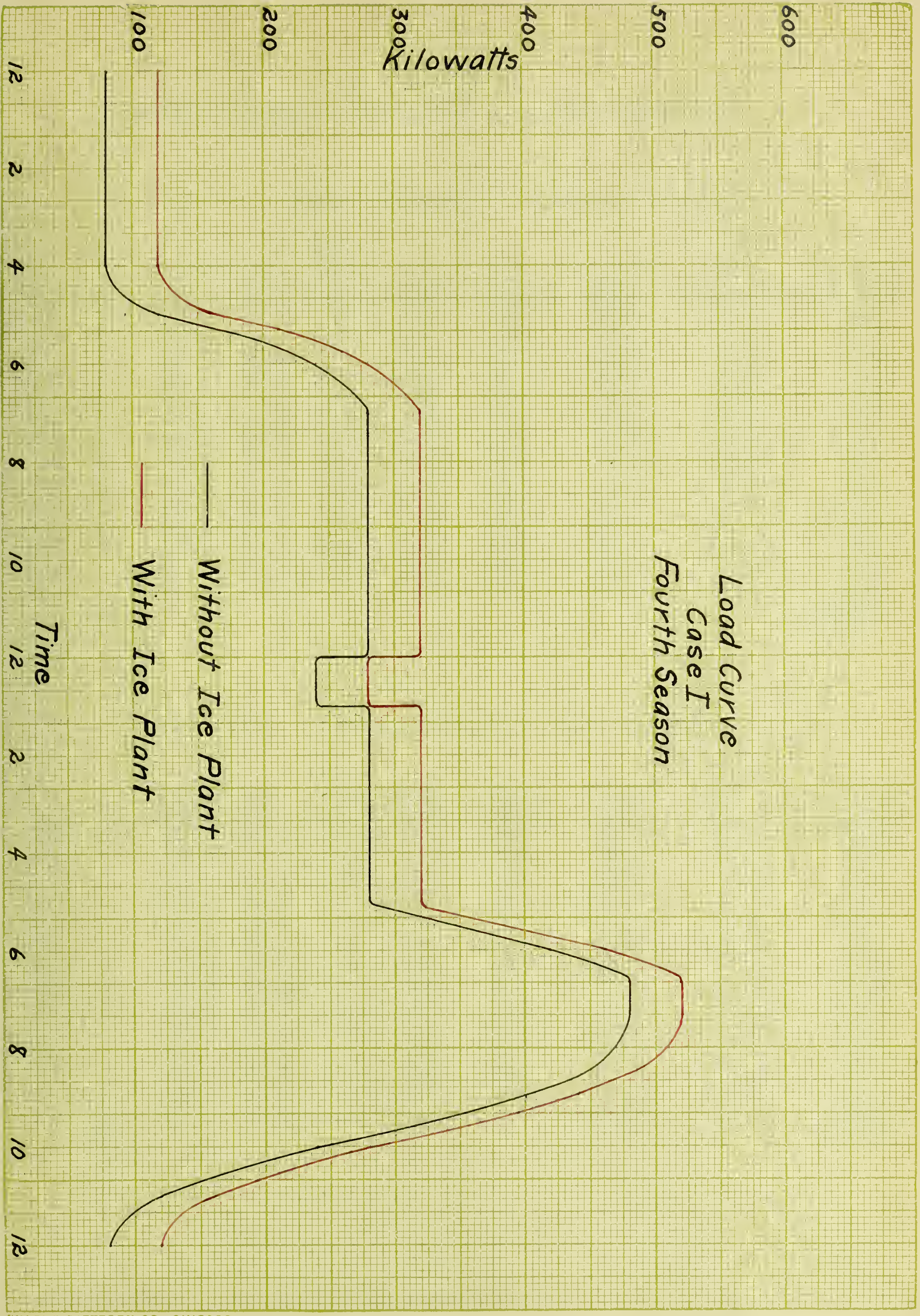
Third Season,--June -July -August.

TABLE V. Steam Consumption without Ice-plant.

K.W.	Hr.	% Load Gen.	Gen. Eff.	Input Gen. K.W.	Eng. B.H.P.	Eng. I.H.P.	% Load Eng.	# Steam per I.H.P. Hr.	# Steam Total
80	3.5	40.0	84.5	95	127	138	46.0	18.4	8900
60	.5	30.0	75.5	79	106	115	38.6	19.5	1130
70	1.0	35.0	80.0	87	117	127	42.4	19.0	2410
120	1.0	60.0	92.0	130	175	190	63.3	16.1	3030
200	1.0	100.0	95.0	210	281	306	102.0	14.0	4290
240	3.0	80.0	94.0	256	343	372	81.1	15.0	16750
260	1.0	86.6	94.5	275	369	401	87.2	14.5	5830
275	1.0	91.6	95.0	290	388	422	91.8	14.2	6000
280	5.0	93.3	95.0	294	394	429	93.2	14.2	30450
285	1.0	95.0	95.0	300	402	437	95.0	14.0	6120
315	1.0	105.0	95.0	332	445	484	105.0	14.0	6780
370	1.0	74.0	94.0	394	527	573	75.5	15.2	8720
295	1.0	98.4	95.0	310	416	452	98.4	14.0	6330
260	1.0	86.6	94.5	275	369	401	87.2	14.5	5830
200	1.0	100.0	95.0	210	282	306	102.0	14.0	4290
120	1.0	60.0	92.0	130	175	190	63.3	16.1	3030
	24.0								119890

TABLE VI. Steam Consumption with Ice-plant.

K.W.	Hr.	% Load Gen.	Gen. Eff.	Input Gen. K.W.	Eng. B.H.P.	Eng. I.H.P.	% Load Eng.	# Steam per I.H.P. Hr.	# Steam Total
165	3.5	82.5	95.0	174	233	253	84.4	14.9	13200
145	.5	72.5	93.5	155	208	226	75.4	15.2	1720
155	1.0	77.5	94.0	165	220	240	80.0	15.0	3600
205	1.0	102.5	95.0	216	289	314	104.6	14.0	4400
285	1.0	95.0	95.0	300	402	437	95.0	14.0	6120
325	3.0	108.3	95.0	342	458	498	108.2	14.0	20900
345	1.0	69.0	93.0	371	497	540	71.1	15.6	8430
360	1.0	72.0	93.0	385	515	560	73.6	15.5	8700
365	5.0	73.0	93.5	390	522	567	74.6	15.5	44000
370	1.0	74.0	94.0	394	527	573	75.5	15.2	8720
400	1.0	80.0	94.0	425	570	620	81.5	14.8	9166
455	1.0	91.0	95.0	479	641	697	91.7	14.3	9970
380	1.0	76.0	94.0	404	541	589	77.4	15.1	8900
345	1.0	69.0	93.0	371	497	540	71.1	15.6	8430
285	1.0	95.0	95.0	300	402	437	95.0	14.0	6120
205	1.0	102.5	95.0	216	289	314	104.6	14.0	4400
	24.0								166776


Load Curve
Case I
Fourth Season
Kilowatts
100
200
300
400
500
600
Without Ice Plant
With Ice Plant
Time
12
2
4
6
8
10
12
2
4
6
8
10
12

CASE I.

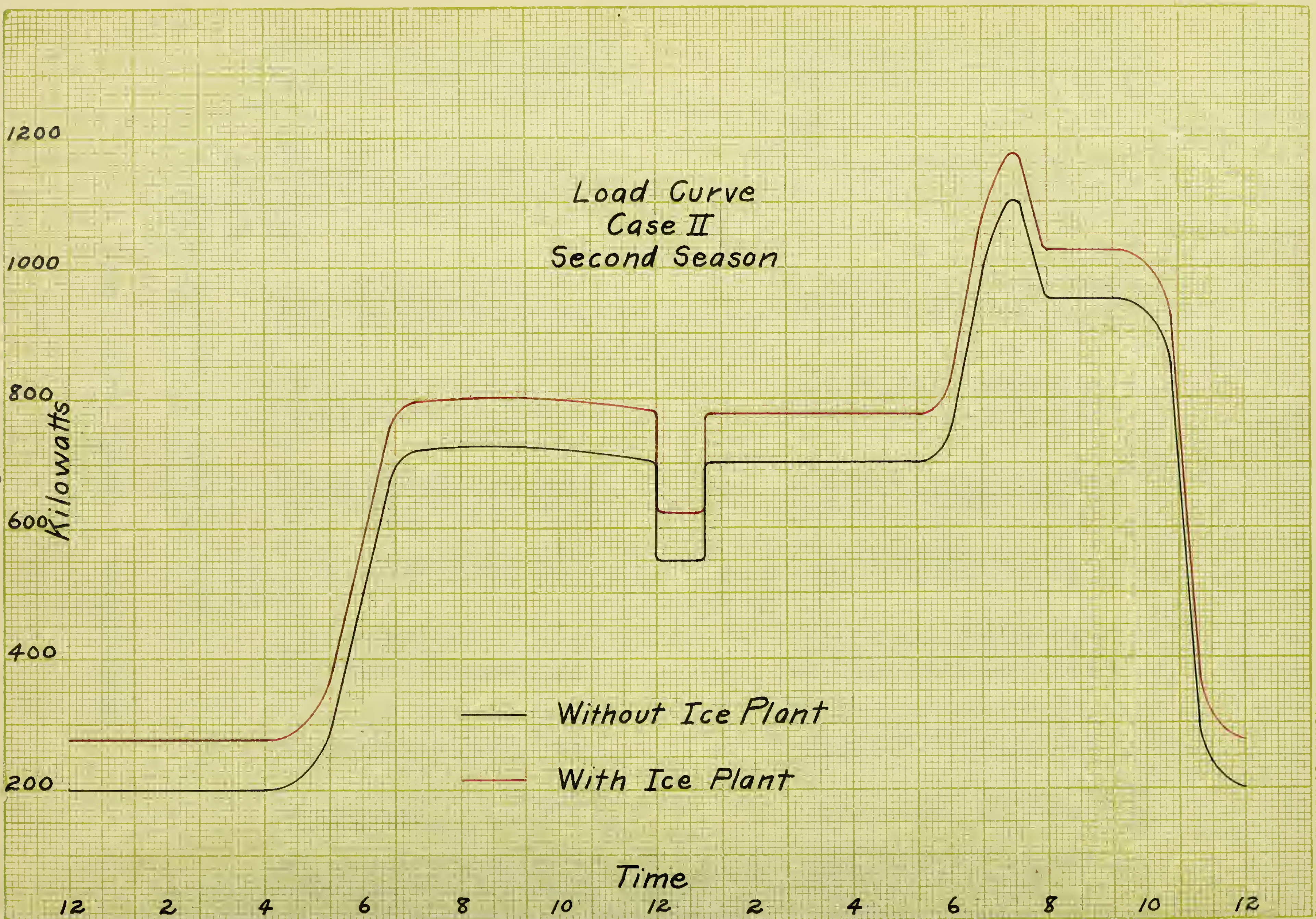
Fourth Season,-- September - October- November.

TABLE VII. Steam Consumption without Ice-plant.

K.W.	Hr.	% Load Gen.	Gen. Eff.	Input Gen. K.W.	Eng. B.H.P.	Eng. I.H.P.	% Load Eng.	# Steam per I.H.P. Hr.	# Steam Total
80	4	40.0	84.5	95	127	138	46.0	18.4	10180
100	1	50.0	90.0	111	149	162	53.8	17.4	2820
180	1	90.0	95.0	189	254	276	92.0	14.2	3920
260	1	86.6	94.5	275	369	401	87.2	14.5	5830
280	5	93.3	95.0	294	394	429	93.2	14.2	30450
240	1	80.0	94.0	256	343	372	80.1	15.0	5580
280	4	93.3	95.0	294	394	429	93.2	14.2	24400
350	1	70.0	93.5	374	500	544	71.5	15.8	8600
450	1	90.0	95.0	474	635	690	91.0	14.2	9800
470	1	94.0	95.0	495	664	722	95.0	14.1	10180
430	1	86.0	94.5	455	610	664	87.4	14.5	9630
320	1	64.0	92.5	346	464	505	66.5	16.0	8080
180	1	90.0	95.0	189	254	276	92.0	14.2	3920
100	1	50.0	90.0	111	149	162	54.0	17.4	2820
	24								136210

TABLE VIII. Steam Consumption with Ice-plant.

K.W.	Hr.	% Load Gen.	Gen. Eff.	Input Gen. K.W.	Eng. B.H.P.	Eng. I.H.P.	% Load Eng.	# Steam per I.H.P. Hr.	# Steam Total
120	4	60.0	92.0	130	175	190	63.3	16.1	12120
140	1	70.0	93.5	150	201	218	72.6	15.5	3380
220	1	73.3	93.5	235	315	343	74.6	15.5	5320
300	1	100.0	95.0	316	424	461	100.0	14.0	6460
320	5	107.0	95.0	338	450	489	106.2	14.0	34300
280	1	93.3	95.0	294	394	429	93.2	14.2	6090
320	4	107.0	95.0	336	450	489	106.2	14.0	27400
390	1	78.0	94.0	415	556	605	79.5	15.0	9080
490	1	98.0	95.0	516	692	752	99.0	14.0	10500
510	1	102.0	95.0	536	719	781	103.0	14.0	10920
470	1	94.0	95.0	495	664	722	95.0	14.1	10180
360	1	72.0	93.5	385	515	560	73.6	15.5	8690
220	1	73.3	93.5	235	315	343	74.6	15.5	5320
140	1	70.0	93.5	150	201	218	72.6	15.5	3380
	24								153140


Load Curve
Case II
Second Season
1200
1000
800
600
400
200
Kilowatts
Without Ice Plant
With Ice Plant
Time
12
2
4
6
8
10
12
2
4
6
8
10
12

CASE II.

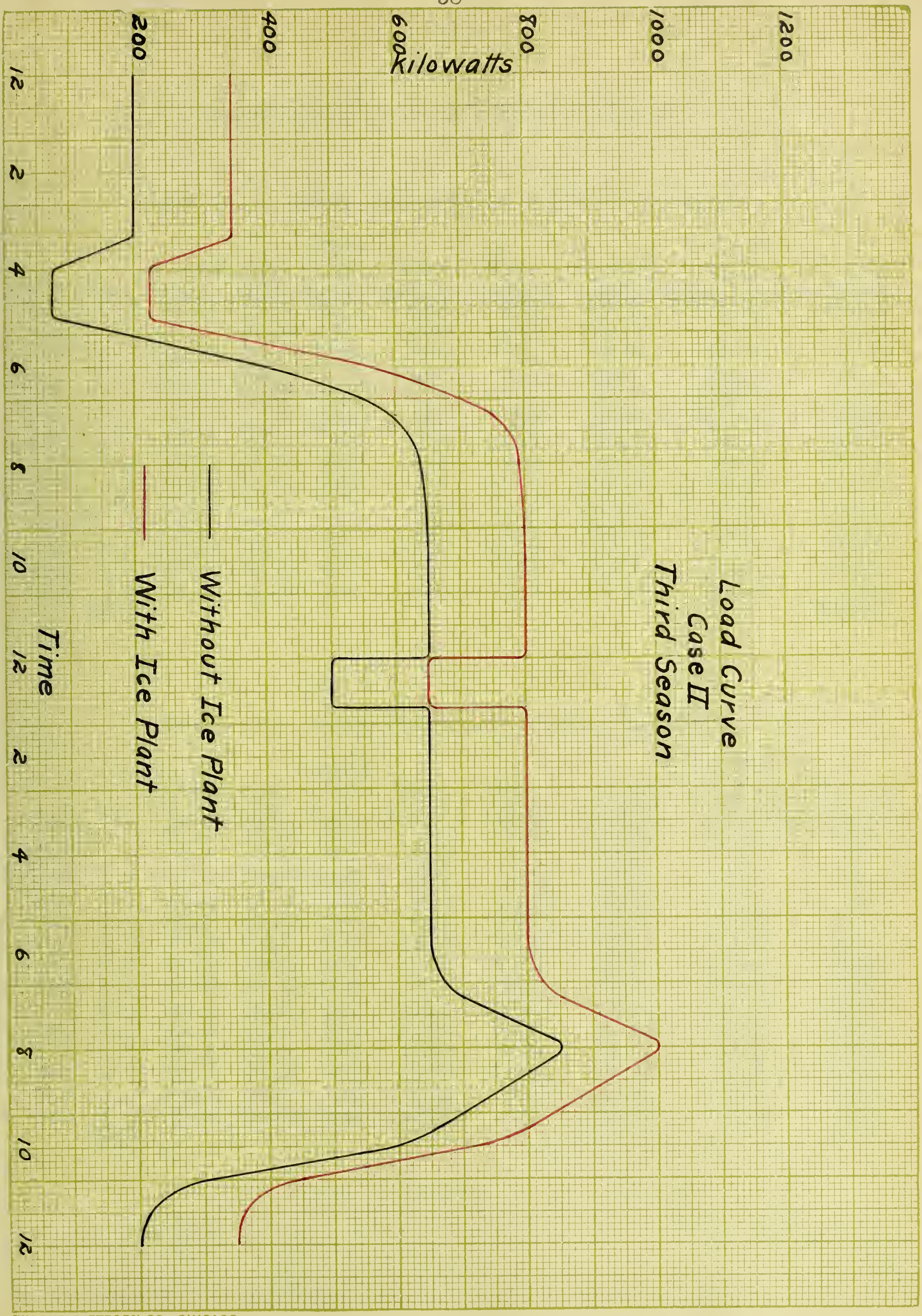
Second Season,-- March - April - May.

TABLE I. Steam Consumption without Ice-plant.

K.W.	Hr.	% Load Gen.	Gen. Eff.	Input Gen. K.W.	Eng. B.H.P.	Eng. I.H.P.	% Load Eng.	# Steam per I.H.P. Hr.	# Steam Total
220	4.0	73.3	93.5	235	315	343	74.6	15.5	21280
225	1.0	75.0	94.0	239	320	348	76.0	15.2	5280
380	1.0	54.3	91.0	417	559	609	60.9	16.8	10220
625	1.0	89.4	95.0	658	882	960	96.0	14.0	13440
725	3.0	103.5	95.0	763	1022	1112	111.2	14.1	47100
710	2.0	101.5	95.0	748	1000	1090	109.0	14.0	30500
550	1.0	78.6	94.0	585	785	855	85.5	14.7	12550
710	4.5	101.5	95.0	748	1000	1090	109.0	14.0	68700
725	.5	103.5	95.0	763	1022	1112	111.2	14.0	7850
925	1.0	92.5	95.0	974	1305	1420	97.3	14.0	19900
975	1.0	97.5	95.0	1025	1372	1492	102.0	14.0	20900
900	2.0	90.0	95.0	947	1270	1380	94.5	14.1	38900
625	1.0	89.4	95.0	657	882	960	96.0	14.0	13440
275	1.0	91.6	95.0	290	388	422	91.7	14.2	5980
	24.0								316030

TABLE II. Steam Consumption with Ice-plant.

K.W.	Hr.	% Load Gen.	Gen. Eff.	Input Gen. K.W.	Eng. B.H.P.	Eng. I.H.P.	% Load Eng.	# Steam per I.H.P. Hr.	# Steam Total
275	4.0	91.6	95.0	290	388	422	91.7	14.2	23920
300	1.0	100.0	95.0	316	424	461	100.0	14.0	6460
455	1.0	65.0	92.5	492	660	718	71.8	15.8	11340
700	1.0	100.0	95.0	738	990	1078	107.8	14.0	15100
800	3.0	80.0	94.0	851	1140	1240	85.0	14.8	55140
785	2.0	78.5	94.0	835	1120	1220	83.5	14.9	36400
625	1.0	62.5	92.5	676	906	986	67.5	16.0	15780
785	4.5	78.5	94.0	835	1120	1220	83.5	14.9	82000
800	.5	80.0	94.0	851	1140	1240	85.0	14.7	9120
1000	1.0	100.0	95.0	1050	1405	1529	104.5	14.0	21400
1050	1.0	105.0	95.0	1102	1480	1610	110.0	14.0	22550
975	2.0	97.5	95.0	1025	1372	1492	102.0	14.0	41800
700	1.0	100.0	95.0	738	990	1078	107.8	14.0	15100
350	1.0	116.6	95.0	368	494	537	117.0	14.1	7580
	24.0								363690


Kilowatts
200
400
600
800
1000
1200
Load Curve
Case II
Third Season
Without Ice Plant
With Ice Plant
Time
12
2
4
6
8
10
12
2
4
6
8
10
12

CASE II.

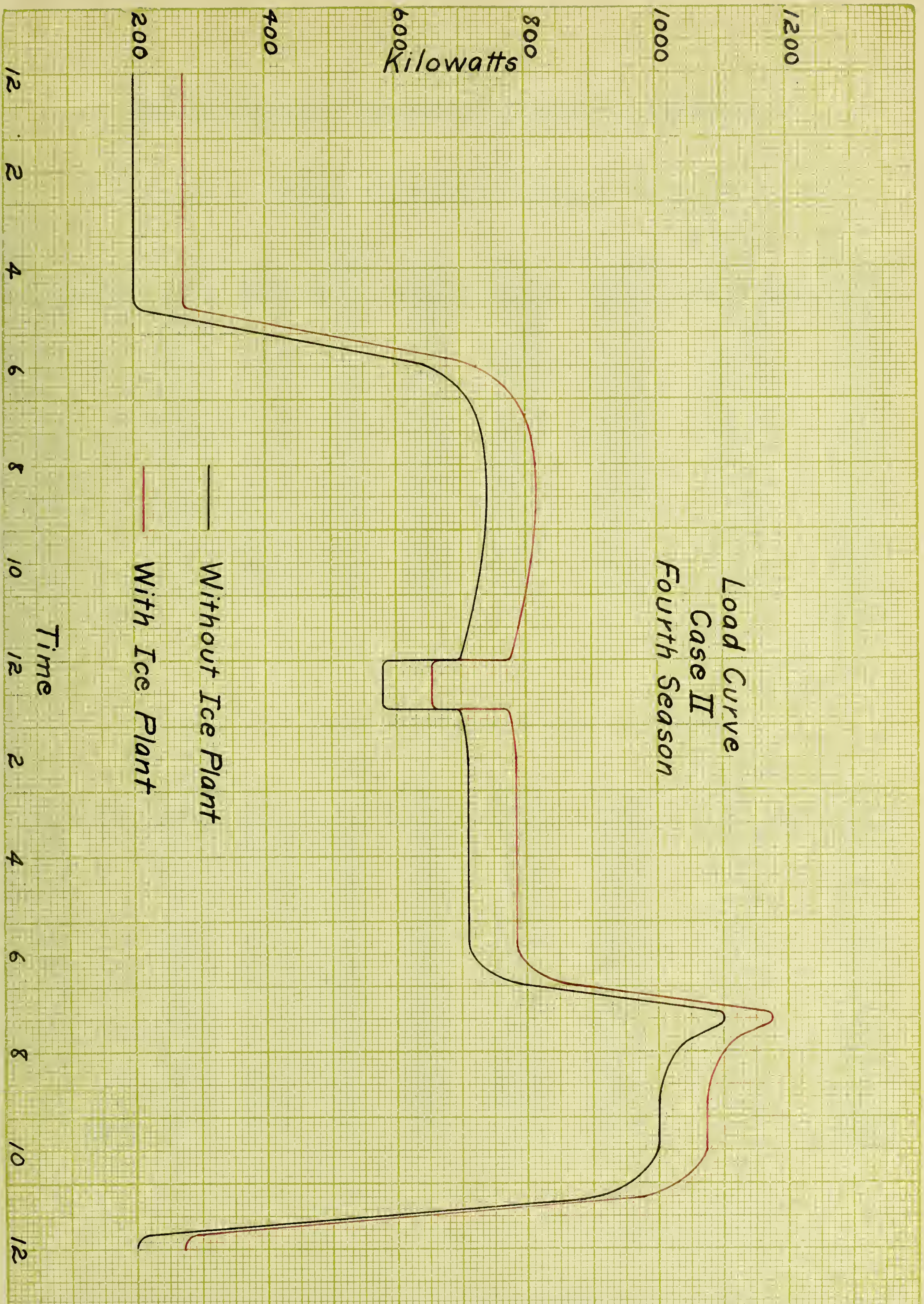
Third Season,-- June - July - August.

TABLE III. Steam Consumption without Ice-plant.

K.W.	Hr.	% Load Gen.	Gen. Eff.	Input Gen. K.W.	Eng. B.H.P.	Eng. I.H.P.	% Load Eng.	# Steam per I.H.P. Hr.	# Steam Total
200	3.5	66.6	93.0	215	288	307	67.0	16.0	17200
125	.5	41.6	85.5	146	195	212	46.5	18.2	1930
75	1.0	25.0	70.0	107	143	156	34.0	20.0	3120
240	1.0	80.0	94.0	255	342	372	81.0	15.0	5590
525	1.0	75.0	94.0	559	749	815	81.5	15.0	12200
625	1.0	89.4	95.0	658	882	960	96.0	14.0	13440
650	4.0	93.0	95.0	685	919	1000	100.0	14.0	56000
500	1.0	71.5	93.5	535	716	780	78.0	15.0	11700
650	5.0	93.0	95.0	685	919	1000	100.0	14.0	70000
675	1.0	96.5	95.0	710	952	1035	103.5	14.0	14500
775	1.0	110.6	94.5	820	1100	1196	119.6	14.2	16960
730	2.0	104.2	95.0	768	1030	1120	112.0	14.0	31400
435	1.0	62.1	92.0	473	634	690	69.0	15.7	10830
210	1.0	70.0	93.0	226	303	329	71.6	15.6	5140
	24.0								270010

TABLE IV. Steam Consumption with Ice-plant.

K.W.	Hr.	% Load Gen.	Gen. Eff.	Input Gen. K.W.	Eng. B.H.P.	Eng. I.H.P.	% Load Eng.	# Steam per I.H.P. Hr.	# Steam Total
350	3.5	50.0	90.0	389	522	568	56.8	17.0	33800
275	.5	91.6	95.0	290	388	422	91.7	14.2	2990
225	1.0	75.0	94.0	239	320	348	76.0	15.2	5280
390	1.0	55.8	91.0	428	574	625	62.5	16.1	10300
675	1.0	96.5	95.0	710	952	1035	103.5	14.0	14500
775	1.0	77.5	94.0	825	1105	1200	82.5	14.9	17900
800	4.0	80.0	94.0	851	1140	1240	85.0	14.8	73500
650	1.0	65.0	92.5	703	941	1022	70.0	15.8	16200
800	5.0	80.0	94.0	851	1140	1240	85.0	14.8	91900
825	1.0	82.5	94.0	878	1175	1275	87.4	14.4	18380
925	1.0	92.5	95.0	975	1305	1420	97.3	14.1	20000
880	2.0	88.0	94.5	932	1248	1355	92.8	14.3	38800
585	1.0	83.5	94.5	620	830	902	90.2	14.2	12800
360	1.0	51.4	90.0	400	536	583	58.3	16.8	9800
	24.0								366150


Kilowatts
200
400
600
800
1000
1200
Load Curve
Case II
Fourth Season
Without Ice Plant
With Ice Plant
Time
12
2
4
6
8
10
12
2
4
6
8
10
12

CASE II.

Fourth Season,-- September - October - November.

TABLE V. Steam Consumption without Ice-plant.

K.W.	Hr.	% Load Gen.	Gen. Eff.	Input Gen. K.W.	Eng. B.H.P.	Eng. I.H.P.	% Load Eng.	# Steam per I.H.P. Hr.	# Steam Total
200	4.5	66.6	93.0	215	288	307	67.0	16.0	22100
225	.5	75.0	94.0	239	320	348	76.0	15.2	2640
400	1.0	57.2	91.5	437	585	636	63.6	16.5	10500
700	1.0	100.0	95.0	738	990	1078	107.8	14.0	15100
740	4.0	105.8	95.0	779	1044	1135	113.5	14.1	64100
725	1.0	103.5	95.0	763	1022	1112	111.2	14.1	15700
650	2.0	93.0	95.0	686	919	1000	100.0	14.0	28000
710	4.0	101.5	95.0	748	1000	1090	109.0	14.0	61000
875	1.0	87.5	94.5	925	1240	1350	92.5	14.2	19210
1050	1.0	105.0	95.0	1102	1480	1610	110.0	14.0	22550
910	1.0	91.0	95.0	958	1285	1400	96.0	14.0	19600
900	1.0	90.0	95.0	947	1270	1380	94.5	14.1	19450
875	1.0	87.5	94.5	925	1240	1350	92.5	14.2	19210
500	1.0	71.5	93.5	535	716	780	78.0	15.0	11700
	24.0								330860

TABLE VI. Steam Consumption with Ice-plant.

K.W.	Hr.	% Load Gen.	Gen. Eff.	Input Gen. K.W.	Eng. B.H.P.	Eng. I.H.P.	% Load Eng.	# Steam per I.H.P. Hr.	# Steam Total
275	4.5	91.6	95.0	290	388	422	91.7	14.2	26980
300	.5	100.0	95.0	316	424	461	100.0	14.0	3220
475	1.0	68.0	93.0	510	685	745	74.5	15.3	11400
775	1.0	77.5	94.0	825	1105	1200	82.5	14.9	17900
815	4.0	81.5	94.0	867	1162	1262	86.5	14.7	74400
800	1.0	80.0	94.0	851	1140	1240	85.0	14.8	18380
725	2.0	72.5	93.5	776	1040	1130	77.5	15.1	34150
785	4.0	78.5	94.0	835	1120	1220	83.5	14.9	72800
950	1.0	95.0	95.0	1000	1340	1460	100.0	14.0	20450
1125	1.0	112.5	95.0	1182	1582	1721	118.0	14.1	24300
985	1.0	98.5	95.0	1038	1390	1510	103.5	14.0	21150
975	1.0	97.5	95.0	1025	1372	1492	102.0	14.0	20900
950	1.0	95.0	95.0	1000	1340	1460	100.0	14.0	20450
575	1.0	82.0	94.0	612	821	894	89.4	14.5	12950
	24.0								379430

CASE III.

First Season- - December - January - February.

TABLE I. Steam Consumption without Ice-plant.

K.W.	Hr.	% Load Gen.	Gen. Eff.	Input Gen. K.W.	Eng. B.H.P.	Eng. I.H.P.	% Load Eng.	# Steam per I.H.P. Hr.	# Steam Total
80	3	40.0	84.5	95	127	138	46.0	29.0	12000
95	1	47.5	89.0	106	142	155	51.7	28.0	4340
160	1	80.0	94.0	170	228	247	82.5	24.0	5940
260	1	86.6	94.5	275	369	401	87.2	23.6	9460
300	1	100.0	95.0	316	423	460	100.0	22.6	10400
280	5	93.3	95.0	294	394	429	93.2	23.0	49300
200	1	66.6	93.0	215	288	313	68.1	25.2	7900
280	2	93.3	95.0	294	394	429	93.2	23.0	19750
300	1	100.0	95.0	316	423	460	100.0	22.6	10400
360	1	72.0	93.5	385	515	560	73.6	25.2	14100
500	1	100.0	95.0	526	705	766	100.0	22.6	17300
560	1	112.0	95.0	590	790	860	113.0	22.4	19250
500	1	100.0	95.0	526	705	766	100.0	22.6	17300
480	1	96.1	95.0	505	676	736	96.8	22.8	16800
400	1	80.0	94.0	425	570	620	81.5	24.0	14880
240	1	80.0	94.0	256	343	372	81.1	24.0	8950
120	1	60.0	92.0	130	175	190	63.3	26.4	5010
	24								243080

TABLE II. Steam Consumption with Ice-plant.

K.W.	Hr.	% Load Gen.	Gen. Eff.	Input Gen. K.W.	Eng. B.H.P.	Eng. I.H.P.	% Load Eng.	# Steam per I.H.P. Hr.	# Steam Total
120	3	60.0	92.0	130	175	190	63.3	26.2	15030
135	1	66.6	93.0	145	194	211	70.4	25.2	5320
200	1	100.0	95.0	210	282	306	102.0	22.6	6910
300	1	100.0	95.0	316	423	460	100.0	23.6	10400
340	1	113.0	95.0	358	480	521	113.1	22.4	11680
320	5	107.0	95.0	336	450	489	106.2	22.5	55000
240	1	80.0	94.0	256	343	372	81.1	24.0	8950
320	2	107.0	95.0	336	450	489	106.2	22.5	22000
340	1	68.0	93.0	366	488	530	69.6	25.6	13580
400	1	80.0	94.0	425	570	620	81.5	24.0	14880
540	1	108.0	95.0	570	765	830	109.0	22.5	18700
560	1	112.0	95.0	590	790	860	113.0	22.4	19250
540	1	108.0	95.0	570	765	830	109.0	22.5	18700
520	1	104.0	95.0	548	735	798	105.0	22.5	17950
490	1	98.0	95.5	516	692	752	99.0	22.8	17150
280	1	93.3	95.0	294	394	429	93.2	23.0	9880
160	1	80.0	94.0	170	228	247	82.5	24.0	5940
	24								271320

CASE III.

Second Season,-- March - April - May.

TABLE III. Steam Consumption without Ice-plant.

K.W.	Hr.	% Load Gen.	Gen. Eff.	Input Gen. K.W.	Eng. B.H.P.	Eng. I.H.P.	% Load Eng.	# Steam per I.H.P. Hr.	# Steam Total
80	3	40.0	84.5	95	127	138	46.0	29.0	12000
100	1	50.0	90.0	111	149	162	53.8	27.8	4490
170	1	85.0	94.5	180	241	262	87.3	23.6	6180
240	1	80.0	94.0	256	343	372	81.1	24.0	8950
280	6	93.3	95.0	294	394	429	53.2	23.0	59300
210	1	70.0	93.0	226	302	328	71.4	25.2	8260
280	4	93.3	95.0	294	394	429	93.2	23.2	39500
360	1	72.0	93.5	385	515	560	73.6	25.2	14100
480	1	96.1	95.0	505	676	736	96.8	22.8	16800
500	1	100.0	95.0	526	705	766	100.0	22.6	17300
440	1	88.0	95.0	462	620	679	88.6	23.4	15860
340	1	68.0	93.0	386	488	530	69.6	25.6	13580
220	1	110.0	95.0	232	310	337	112.5	22.4	7550
120	1	60.0	92.0	130	175	190	63.3	26.4	5010
	24								228880

TABLE IV. Steam Consumption with Ice-plant.

K.W.	Hr.	% Load Gen.	Gen. Eff.	Input Gen. K.W.	Eng. B.H.P.	Eng. I.H.P.	% Load Eng.	# Steam per I.H.P. Hr.	# Steam Total
155	3	77.5	94.0	165	220	240	80.0	24.0	17280
175	1	87.5	95.0	184	246	268	89.2	23.2	6220
245	1	81.6	94.5	259	347	377	82.0	24.0	9050
315	1	105.0	95.0	332	445	484	105.0	22.5	10880
355	6	71.0	93.5	380	509	554	72.8	25.0	83100
285	1	57.0	91.5	311	419	455	60.0	22.6	12100
355	4	71.0	93.5	380	509	554	72.8	25.0	55400
435	1	87.0	94.5	460	616	670	88.0	23.4	15680
555	1	111.0	95.0	585	784	852	112.0	22.4	19100
575	1	125.0	94.0	612	820	891	117.0	22.4	19980
515	1	103.0	95.0	542	725	788	103.8	22.5	16880
415	1	83.0	94.5	440	590	641	84.4	23.8	15260
295	1	98.3	95.0	310	416	452	100.0	22.6	10220
195	1	97.5	95.0	205	274	298	99.3	22.6	6750
	24								297900

CASE III.

Third Season- - June - July - August.

TABLE V. Steam Consumption without Ice-plant.

K.W.	Hr.	% Load Gen.	Gen. Eff.	Input Gen. K.W.	Eng. B.H.P.	Eng. I.H.P.	% Load Eng.	# Steam per I.H.P. Hr.	# Steam Total
80	3.5	40.0	84.5	95	127	138	46.0	29.0	14000
60	.5	30.0	75.5	79	106	116	38.6	30.2	1750
70	1.0	35.0	80.0	87	117	127	42.4	29.5	3750
120	1.0	60.0	92.0	130	175	190	63.3	26.4	5010
200	1.0	100.0	95.0	210	281	306	102.0	22.6	6910
240	3.0	80.0	94.0	256	343	372	81.0	24.0	26800
260	1.0	86.6	94.5	275	369	401	87.2	23.6	9500
275	1.0	91.6	95.0	290	388	422	91.8	23.1	9725
280	5.0	93.3	95.0	294	394	429	93.2	23.0	49375
285	1.0	95.0	95.0	300	402	437	95.0	23.0	10050
315	1.0	105.0	95.0	332	445	484	105.0	22.5	10880
370	1.0	74.0	94.0	394	527	573	75.5	24.8	14200
295	1.0	98.4	95.0	310	416	452	98.4	22.8	10300
260	1.0	86.6	94.5	275	369	401	87.2	23.6	9500
200	1.0	100.0	95.0	210	282	306	102.0	22.6	6910
120	1.0	60.0	92.0	130	175	190	63.3	26.4	5010
	24.0								193670

TABLE VI. Steam Consumption with Ice-plant.

K.W.	Hr.	% Load Gen.	Gen. Eff.	Input Gen. K.W.	Eng. B.H.P.	Eng. I.H.P.	% Load Eng.	# Steam per I.H.P.Hr.	# Steam Total
165	3.5	82.5	95.0	174	233	253	84.4	23.8	21100
145	.5	72.5	93.5	155	208	226	75.4	24.8	2800
155	1.0	77.5	94.0	165	226	240	80.0	24.0	5760
205	1.0	102.5	95.0	216	289	314	104.6	22.5	7070
285	1.0	95.0	95.0	300	402	437	95.0	23.0	10050
325	3.0	108.3	95.0	342	458	498	108.2	22.4	33500
345	1.0	69.0	93.0	371	497	540	71.1	25.2	13600
360	1.0	72.0	93.5	385	515	566	73.6	25.2	14100
365	5.0	73.0	93.5	390	522	567	74.6	25.0	70900
370	1.0	74.0	94.0	394	527	573	75.5	24.8	14200
400	1.0	80.0	94.0	425	570	620	81.5	24.0	14880
455	1.0	91.0	95.0	479	641	697	91.7	23.2	16180
380	1.0	76.0	94.0	404	541	589	77.4	24.4	14350
345	1.0	69.0	93.0	371	497	540	71.7	25.2	13600
285	1.0	95.0	95.0	300	402	437	95.0	23.0	10050
205	1.0	102.5	95.0	216	289	314	104.6	22.5	7070
	24.0								269230

CASE III.

Fourth Season,-- September - October - November.

TABLE VII. Steam Consumption without Ice-plant.

K.W.	Hr.	% Load Gen.	Gen. Eff.	Input Gen. K.W.	Eng. B.H.P.	Eng. I.H.P.	% Load Eng.	# Steam per I.H.P. Hr.	# Steam Total
80	4	40.0	84.5	95	127	138	46.0	29.0	16000
100	1	50.0	90.0	111	149	162	53.8	27.8	4490
180	1	90.0	95.0	189	254	276	92.0	23.0	6350
260	1	86.6	94.5	275	369	401	87.2	23.6	9460
280	5	93.3	95.0	294	394	429	93.2	23.0	49300
240	1.	80.0	94.0	256	343	372	80.1	24.0	8950
280	4	93.3	95.0	294	394	429	93.2	23.0	39500
350	1	70.0	93.5	374	500	544	71.5	25.0	13600
450	1	90.0	95.0	474	635	690	91.0	23.2	16000
470	1	94.0	95.0	495	664	722	95.0	23.0	16600
430	1	86.0	94.5	455	610	664	87.4	23.5	15600
320	1	64.0	92.5	346	464	505	66.5	25.8	13030
180	1	90.0	95.0	189	254	276	92.0	23.0	6350
100	1	50.0	90.0	111	149	162	54.0	27.8	4490
	24								219720

TABLE VIII. Steam Consumption with Ice-plant.

K.W.	Hr.	% Load Gen.	Gen. Eff.	Input Gen. K.W.	Eng. B.H.P.	Eng. I.H.P.	% Load Eng.	# Steam per I.H.P. Hr.	# Steam Total
120	4	60.0	92.0	130	175	190	63.3	26.4	20050
140	1	70.0	93.5	150	201	218	72.6	25.0	5450
220	1.	73.3	93.5	235	315	343	74.6	24.9	8540
300	1	100.0	95.0	316	423	460	100.0	22.6	10400
320	5	107.0	95.0	336	450	489	106.2	22.5	55000
280	1	93.3	95.0	294	394	429	93.2	23.0	9880
320	4	107.0	95.0	336	450	489	106.2	22.5	44000
390	1	78.0	94.0	415	556	605	79.5	24.0	14500
490	1	98.0	95.0	516	692	752	99.0	22.6	16980
510	1	102.0	95.0	536	719	781	103.0	22.6	17650
470	1	94.0	95.0	495	664	722	95.6	22.8	16750
360	1	72.0	93.5	385	515	560	73.6	25.2	14100
220	1	73.3	93.5	235	315	343	74.6	24.9	8540
140	1	70.0	93.5	150	210	218	72.6	25.0	5450
	24								247290

CASE IV.

First Season,-- December - January - February.

TABLE I. Steam Consumption with Ice-plant.

K.W.	Hr.	% Load Gen.	Gen. Eff.	Input Gen. K.W.	Eng. B.H.P.	Eng. I.H.P.	% Load Eng.	# Steam per I.H.P. Hr.	# Steam Total
80	3	40.0	84.5	95	127	138	46.0	31.0	12840
95	1	47.5	89.0	106	142	155	51.7	29.8	4620
160	1	80.0	94.0	170	227	247	82.5	25.3	6260
260	1	86.6	94.5	275	369	401	87.2	24.8	9980
300	1	100.0	95.0	316	423	460	100.0	24.0	11040
280	5	93.3	95.0	294	394	429	93.2	24.4	52300
200	1	66.0	93.0	215	288	313	68.1	27.0	8460
280	2	93.3	95.0	294	394	429	93.2	24.4	20900
300	1	100.0	95.0	316	423	460	100.0	24.0	11040
360	1	72.0	93.5	385	515	560	73.6	26.6	14900
500	1	100.0	95.0	526	705	766	100.0	24.0	18400
560	1	112.0	95.0	590	790	860	113.1	23.6	20300
500	1	100.0	95.0	526	705	766	100.0	24.0	18400
480	1	96.1	95.0	505	676	736	96.8	24.0	17680
400	1	80.0	94.0	425	570	620	81.5	25.4	15750
240	1	80.0	94.0	256	343	372	81.1	25.4	9450
120	1	60.0	92.0	130	175	190	63.3	28.0	5340
	24								257660

Second Season,-- March - April - May.

TABLE II. Steam Consumption with Ice-plant.

K.W.	Hr.	% Load Gen.	Gen. Eff.	Input Gen. K.W.	Eng. B.H.P.	Eng. I.H.P.	% Load Eng.	# Steam per I.H.P. Hr.	# Steam Total
80	3	40.0	84.5	95	127	138	46.0	31.0	12840
100	1	50.0	90.0	111	149	162	53.8	29.6	4800
170	1	85.5	94.5	180	241	267	87.3	25.0	6680
240	1	80.0	94.0	256	343	372	81.1	25.6	9530
280	6	93.3	95.0	294	394	429	93.2	24.4	62800
210	1	70.0	93.0	226	302	328	71.4	26.8	8800
280	4	93.3	95.0	294	394	429	93.2	24.4	41800
360	1	72.0	93.5	385	515	560	73.6	26.6	14900
480	1	96.0	95.0	505	676	736	96.8	24.0	17680
500	1	100.0	95.0	526	705	766	100.0	24.0	18400
440	1	88.0	95.0	462	620	679	88.6	24.7	16750
340	1	68.0	93.0	366	488	530	69.6	26.8	14200
220	1	110.0	95.0	232	310	337	112.5	23.6	7960
120	1	60.0	92.0	130	175	190	63.3	28.0	5340
	24								242480

CASE IV.

Third Season,-- June - July - August.

TABLE III. Steam Consumption with Ice-plant.

K.W.	Hr.	% Load Gen.	Gen. Eff.	Input Gen. K.W.	Eng. B.H.P.	Eng. I.H.P.	% Load Eng.	# Steam per I.H.P. Hr.	# Steam Total
80	3.5	40.0	84.5	95	127	138	46.0	31.0	15000
60	.5	30.0	75.5	79	106	116	38.6	32.2	1860
70	1.0	35.0	80.0	88	117	127	42.4	31.4	3990
120	1.0	60.0	92.0	130	175	190	63.3	28.1	5340
200	1.0	100.0	95.0	210	281	306	102.0	24.0	7350
240	3.0	80.0	94.0	256	343	372	81.1	25.6	28600
260	1.0	86.6	94.5	275	369	401	87.2	24.8	9980
275	1.0	91.6	95.0	290	388	422	91.8	24.5	10325
280	5.0	93.3	95.0	294	394	429	93.2	24.4	52250
285	1.0	95.0	95.0	300	402	437	95.0	24.2	10580
315	1.0	105.0	95.0	332	445	484	105.0	23.8	11520
370	1.0	74.0	94.0	394	527	573	75.5	26.3	15080
295	1.0	98.4	95.0	310	416	452	98.4	24.0	10830
260	1.0	86.6	94.5	275	369	401	89.2	24.8	9980
200	1.0	100.0	95.0	210	282	306	102.0	24.0	7350
120	1.0	60.0	92.0	130	175	190	63.3	28.0	5340
	24.0								205375

Fourth Season,-- September - October - November.

TABLE IV. Steam Consumption with Ice-plant.

K.W.	Hr.	% Load Gen.	Gen. Eff.	Input Gen. K.W.	Eng. B.H.P.	Eng. I.H.P.	% Load Eng.	# Steam per I.H.P. Hr.	# Steam Total
80	4.0	40.0	84.5	95	127	138	46.0	31.0	17100
100	1.0	50.0	90.0	111	149	162	53.8	29.6	4800
180	1.0	90.0	95.0	189	254	276	92.0	24.4	6740
260	1.0	86.6	94.5	275	369	401	87.2	24.8	9980
280	5.0	93.3	95.0	294	394	429	93.2	24.4	52300
240	1.0	80.0	94.0	256	343	372	80.1	25.6	9530
280	4.0	93.3	95.0	294	394	429	93.2	24.4	41800
350	1.0	70.0	93.5	374	500	544	71.5	26.8	14580
450	1.0	90.0	95.0	474	635	690	91.0	24.6	17000
470	1.0	94.0	95.0	495	664	722	95.0	24.2	17470
430	1.0	86.0	94.5	455	610	664	87.4	24.8	16460
320	1.0	64.0	92.5	346	464	505	66.5	27.2	13740
180	1.0	90.0	95.0	189	254	276	92.0	24.4	6740
100	1.0	50.0	90.0	111	149	162	53.8	29.6	4800
	24.0								233040